Concepts and Challenges for Environmentally Friendly En route Operations

Banavar Sridhar

NASA

National Challenges and Goals*

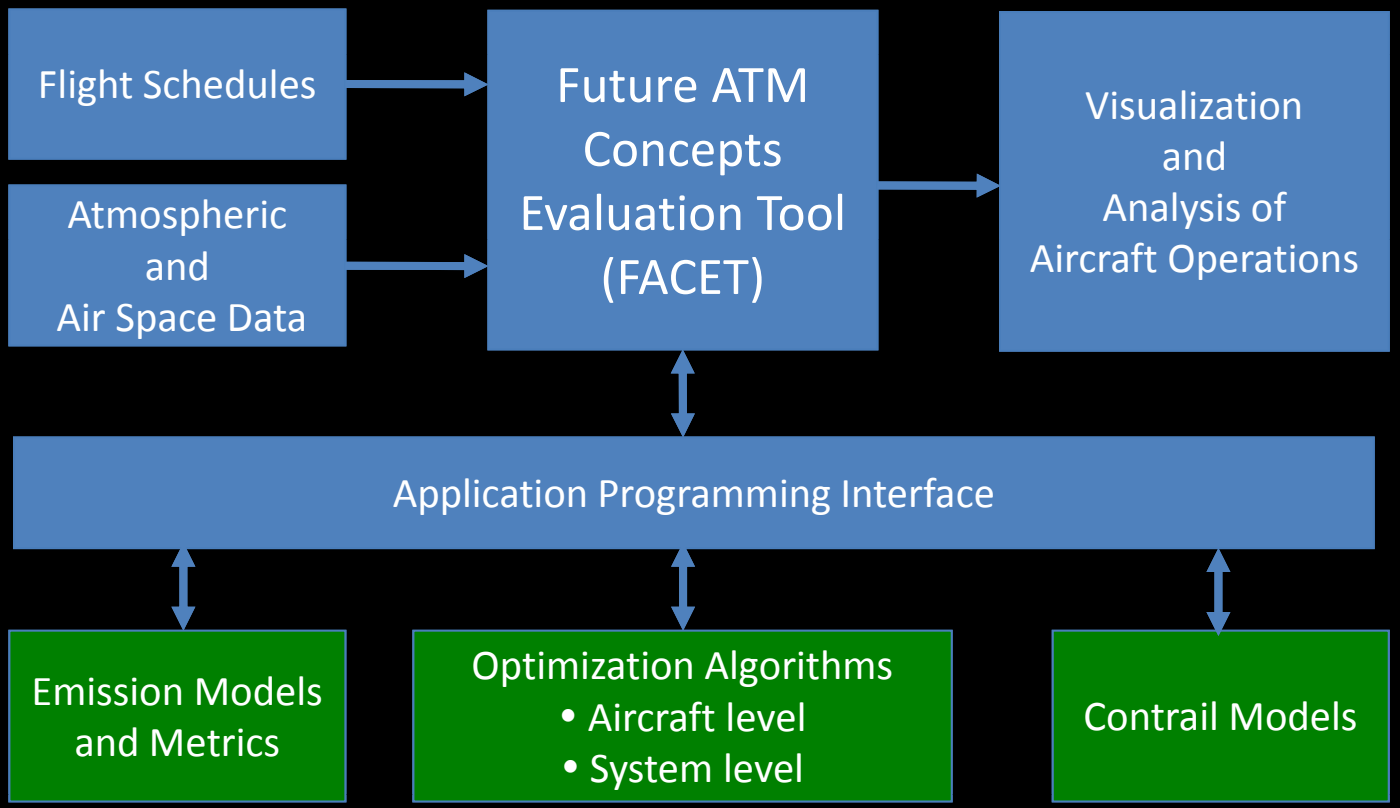
- Challenges
  - Understand the complex relationships between aircraft noise, emissions and fuel burn
  - Optimize aircraft noise, fuel efficiency and emission reductions using advanced technology, operational procedure and computational models
- Goals
  - Enable significant increases in the energy efficiency
  - Decrease the environmental impact

* National Aeronautics Research and Development Plan (February 2010)

Goals of Current Research

- Develop en route traffic flow concepts to reduce environmental impact of aviation based on advances in basic research on climate science
  - Contrails and Cirrus
  - Trade-offs amongst emissions impacting climate

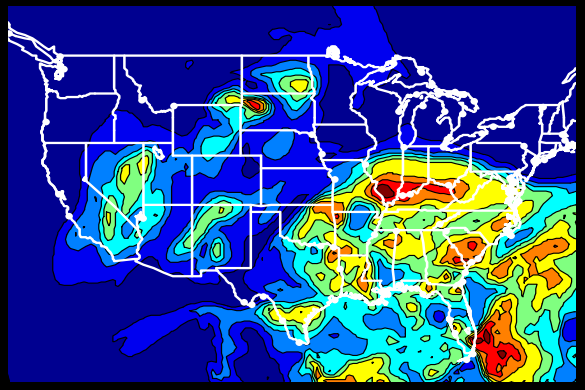
Traffic Flow Simulation Interaction with Other Modules



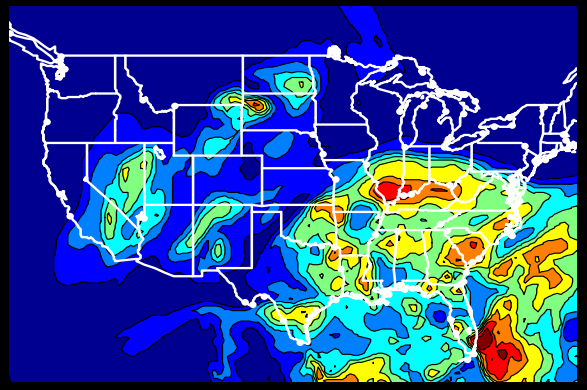
Contrails

- Occur if ambient conditions along the aircraft trajectory is colder and moister than a threshold defined by thermodynamic parameters
- Contrails persist under certain conditions (Relative humidity with respect to ice >100%)
- Effect different during night and day

Persistent Contrail Formation Model

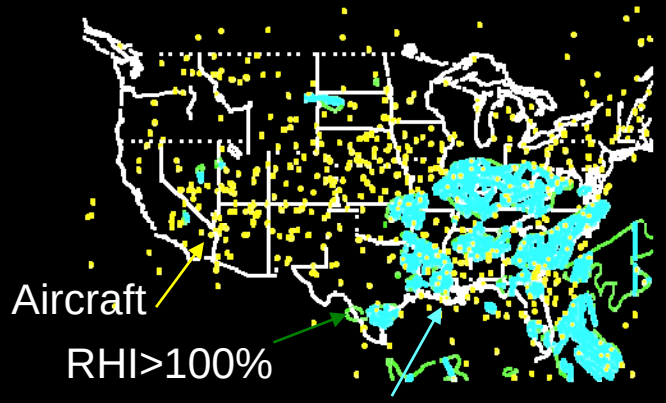


RHW Contours



RHI Contours

RHI>100% Contours

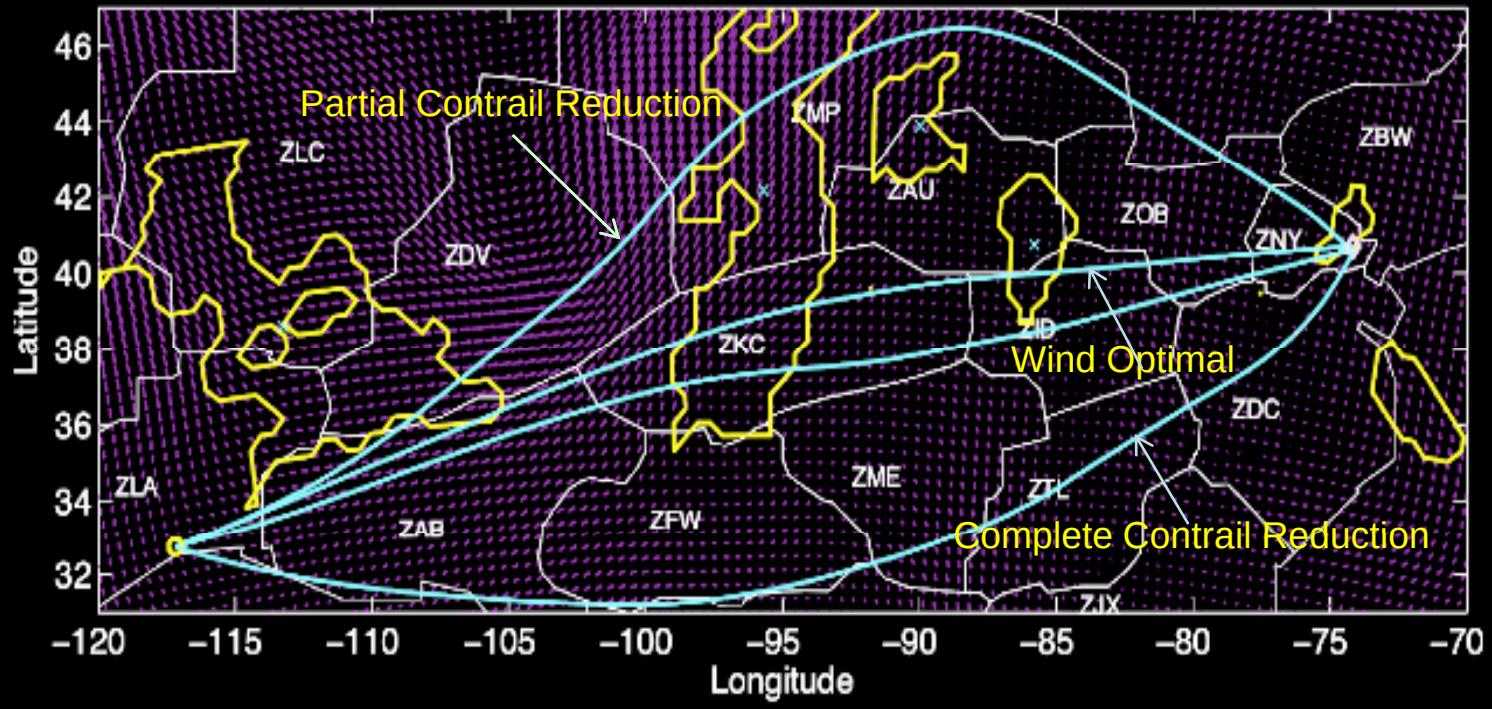


Persistent Contrail

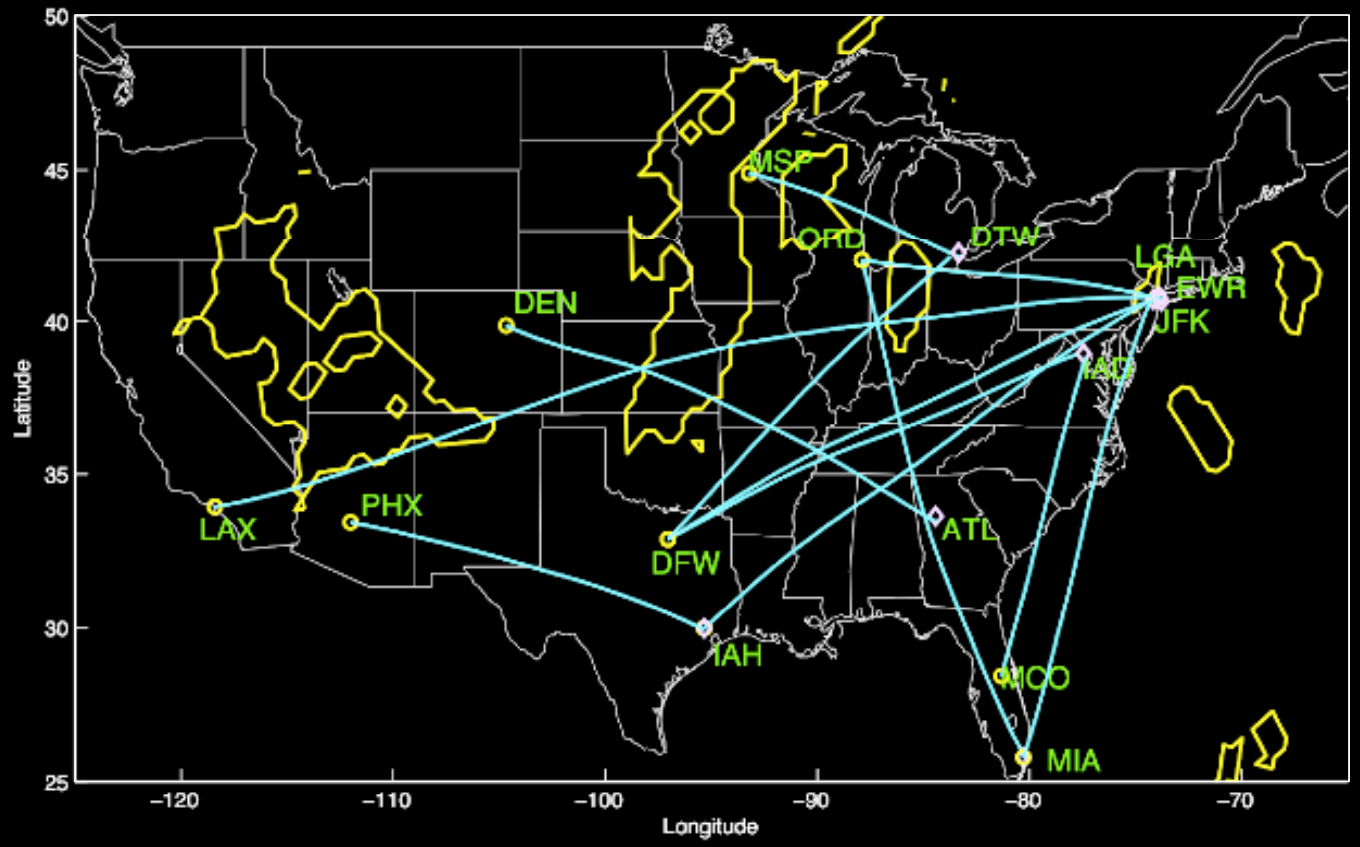
Strategies for Avoiding Contrails

- Tactical
  - Requires on-board sensors to detect super-saturated air
  - Research aircraft equipped with sensors at DLR
  - Air Traffic Service Provider (ATSP) needs to accommodate changes to the flight plans
- Strategic
  - Models for predicting contrails
- Both strategies may result in extra fuel burn
- Research question: How to trade off the extra fuel burn with the environmental impact of going through contrails?
  - Impact of non-CO_2 components of aviation on climate change is significant, but large uncertainty in the contribution of contrails
  - Time scales in the effects of CO_2 (decades) and contrails (hours)

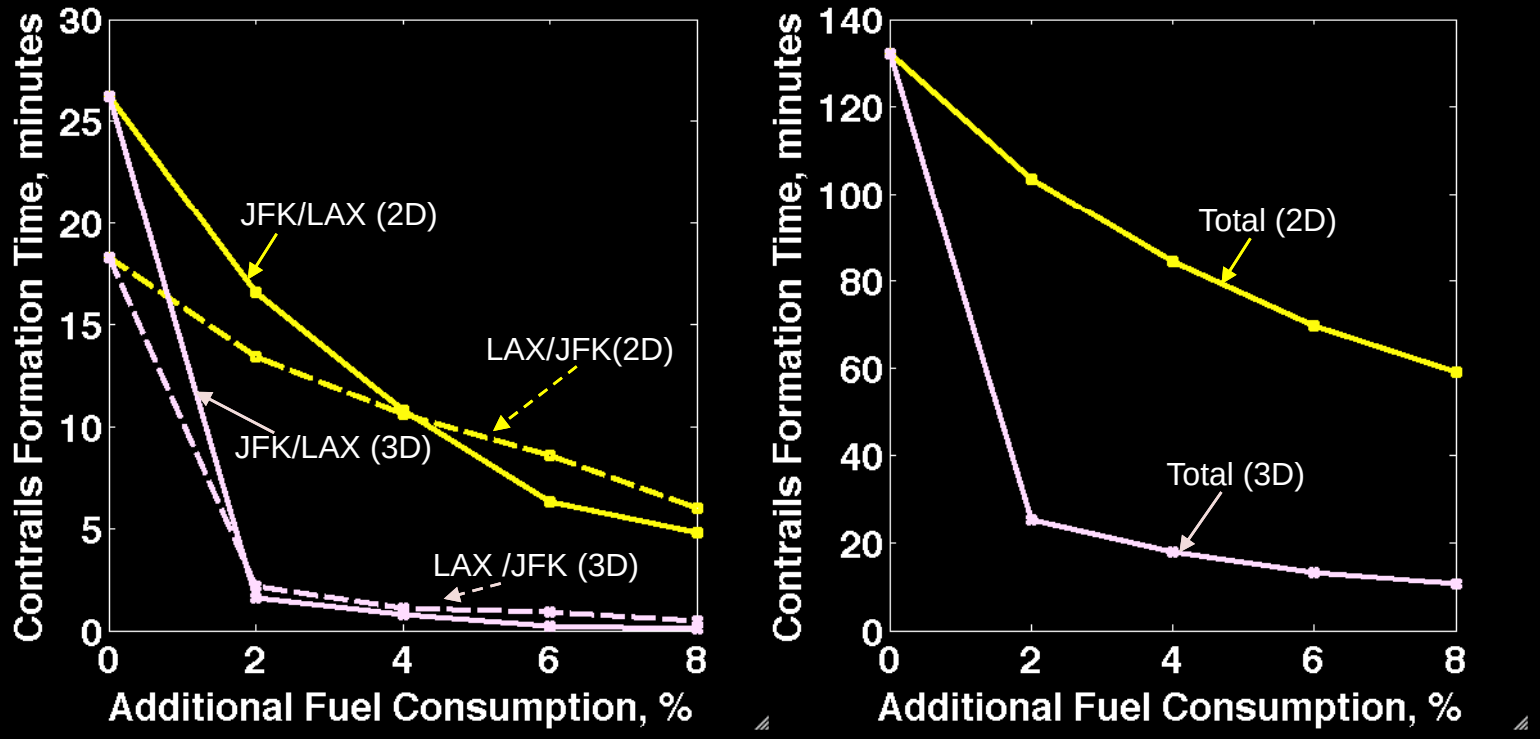
Contrail Reducing Aircraft Trajectories



Travel between 12 City-pairs



Tradeoff between Contrail Reduction and Extra Fuel Consumption



Concluding Remarks

- Presented research on environmentally friendly en route traffic flow concepts incorporating models developed by basic climate research
- Developed an optimal contrail reduction trajectory concept
- Integrated fuel flow, emissions and optimization models with FACET
  - Verified it against FAA emission models
  - Ability to conduct system level analysis of Traffic Flow Management concepts with minimal environmental impact